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BIOLOGICAL INDIVIDUALITY OF MAN

C. Jelleff Carr, et al

Federation of American Societies for Experimental Biology

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This report suggests that the concept of biological individuality is worthy of study as a means of identifying those persons who possess unique attributes or inadequacies for specific tasks or responsibilities. Many biological factors related to individual differences are known and can be quantified objectively and thus may permit the prediction of some performance capability of an individual. The background of work on biological individuality is reviewed, three examples are cited, and key investigators

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BIOLOGICAL INDIVIDUALITY OF MAN

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Human Resources Research Office
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by

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FOREWORD

The Life Sciences Research Office (LSRO), Federation of American Societies for Experimental Biology (FASEB), provides scientific assessments of topics in the biomedical sciences. Reports are based upon comprehensive literature reviews and the scientific opinions of knowledgeable investigators engaged in research in specific areas of biology and medicine.

This technical report was prepared for the Human Resources Research Office, Defense Advanced Research Projects Agency (DARPA), Department of Defense, under contract number F44620-74-C-0077 monitored by the Air Force Office of Scientific Research.

The Life Sciences Research Office acknowledges the contributions of the investigators and consultants who have assisted with this study. The report reflects the opinions expressed by participants in meetings held at Beaumont House, FASEB, and other consultants. A judicious attempt has been made to incorporate the different views and opinions, however, the authors accept responsibility for the contents of the report. The listing of the consultants' names in Section V does not imply that they endorse the conclusions of the study.

The report has been reviewed and approved by the LSRO Advisory Committee (which consists of representatives of each constituent society of FASEB) under authority delegated by the Executive Committee of the Federation Board. Upon completion of these review procedures the report has been approved and transmitted to DARPA by the Executive Director, FASEB.

While this is a report of the Federation of American Societies for Experimental Biology, it does not necessarily reflect the opinion of all of the individual members of its constituent societies.

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SUMMARY AND CONCLUSIONS

This report suggests that the concept of biological individuality is worthy of study as a means of identifying those persons who possess unique attributes or inadequacies for specific tasks or responsibilities. Many biological factors related to individual differences are known and can be quantified objectively and thus may permit the prediction of some performance capability of an individual. The background of work on biological individuality is reviewed, three examples are cited, and key investigators in these specific fields are identified. However, numerous other examples can be found to illustrate the effects of individual biological factors that impinge on human performance. The suggestions for future research emphasize the basic concerns for performance in a military environment that may reflect the expression of biological individuality.

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I. INTRODUCTION

The successful application of biometrics to population problems and epidemiological questions has overshadowed the potential value of the study of the individual. The need to overcome and work with the phenomena of individual differences in animals and man led to the development of the science of biometrics to give statistical validity to data obtained from the study of groups exposed to controlled experimental conditions. For the investigator, differences within groups are frustrating and to be avoided. In biological studies the ability to replicate a response in each individual is a virtue diligently pursued and seldom does the research worker study the relatively few members of a cohort who do not respond in a manner resembling the majority. This paper will focus on the lesser known but equally important issue of individual uniqueness because each has its place in research programs.

For the past 20 years the concept of biological individuality has attracted the attention of a few scientists principally interested in human behavior, enzymology, anatomy, physiology, pharmacology, and biochemistry. Some of these issues have been explored and developed in the writings of Williams (1956) and a few others. As early as 1930 Leo Loeb in a remarkably perceptive review outlined the major facets of the difficulties of transplantation of tissues and organs that reflect the individuality of the organism. However, research on an understanding of the factors that determine individuality has remained essentially dormant.

Darwin recognized the importance of individual differences as indispensable to evolution. Early taxonomists noted the influence of environment on the morphologic characteristics of various species of animals. However, few investigators have attempted to ascertain the fundamental biological determinants of individuality. Only recently, have genetic influences been investigated and the potentialities for future control of biological differences been recognized. These include not only anatomic features but also physiological and biochemical variables. For example, identified hereditary disorders in man with so-called inborn errors of metabolism may be treated by correcting the enzyme deficiencies. The understanding of such differences leads to fundamentally new approaches to numerous biological issues.

The military implications of studies on individual variability are obvious when considered from the standpoint of adaptability of the individual man for such skills as special task training, language facility, or technical proficiency. However, available evidence demonstrates that those individuals more readily adapted to such variables as temperature extremes, motion

or isolation may be identified. The development of these techniques is just beginning but the opportunities for future refinement and applications are enormous. This approach to the maximum utilization of the best individual capabilities of a man by selection based on objective criteria is a further refinement of the long-established practice of the military to most efficiently utilize the manpower pool.

Numerous factors of critical military importance are involved that need investigation to determine ranges of performance capabilities. Important advances in military personnel effectiveness could result from application of an improved understanding of individual differences in the functioning of the special senses, human reliability, physical fitness and endurance, tolerance for physical, chemical, and psychological stresses, and the neurophysiological and biochemical correlates of stress, disturbed biorhythms, sleep deprivation, and fatigue. The physiologic, behavioral, and biochemical aspects of task loading, attention span, concentration versus distractability, and "error proneness" in a typical operational milieau need combined disciplinary investigation with such military variables as sustained operations in difficult tactical and environmental situations.

The scientific literature is replete with examples of basic discoveries that developed from investigations of the causes of individual differences: unusual resistance to disease, unexpected response to a usual dose of a drug, anatomical deviations, eccentric nutritional requirements, and enzymic idiosyncrasies in disease states. Unusual success has followed such inquiries on the causes of susceptibility to infectious diseases, responses to drug therapy, resistance to toxicity of chemicals, unique nutritional requirements, and similar physiological and biochemical idiosyncrasies.

The inherited resistance by a few individuals to the infectious diseases and starvation fatal to many in the great pandemics of history has been recognized by Motulsky (1960) and others. This was a process of human natural selection that led to our present populations with their characteristics of resistance to disease and their inborn differences in physical, physiological, and mental abilities.

It is proposed that biological individuality may be worthy of study as a means to identify those persons who possess unique attributes or inadequacies for specific tasks or responsibilities. The criteria used would be any measurable parameter of biology. Thus, selection of men for night vision proficiency could be based primarily on genetically determined factors of ocular metabolism in the dark-adapted eye. Unusual tolerance or susceptibility to temperature extremes or stresses of motion and noise may be associated with an imbalance in the autonomic nervous system in some individuals. Investigations related to biorhythms, diurnal fluctuations,

endocrine cycles, and aperiodic changes in physiological functions may offer significant information on individual performance ability (Simonson, 1966; Weyev *et al.*, 1966).

In addition to differences among individuals the question of variations within the person from time to time is significant and worthy of study. Thus, even when variability between individuals is recognized in population studies the problem of intra-individual variability remains obscure (McGammon, 1966).

In this review these issues are developed and evaluated as a background for suggestions for future research emphasis as they relate to basic concerns for performance in a military environment and as a basis for predicting the likelihood of success for studies of this character.

An attempt has been made to name key investigators identified in these studies, especially those interested in individual performance variables related to three examples cited. The selections are based in large measure on prior studies conducted on reviews of the sensory modalities of man as related to military performance requirements.

II. THE CONCEPT OF INDIVIDUAL VARIABILITY

A. BACKGROUND

The presumed fundamental requirement for a "normal" or "average" value of a measurable phenomenon poses a unique problem in biology. The statistical treatment of biological data, influenced by such factors as experimental techniques, inherent variation in individual values, and problems in sampling techniques is one way to express biological variation.

The classical orientation of biological research has been to derive generalizations from observational data that describe inherent universal principles. Experiments and observations are made on individual organisms or isolated systems, and from these the investigator attempts to deduce those common features that apply to all individuals or to extract that aspect which is common to all circumstances. The investigator attempts to avoid consideration of individuals *per se* by studying large numbers of subjects and treating the observational data statistically. Individual variability is minimized by repetitive experimentation or use of large numbers of individuals. If results are highly variable and no general mechanisms can be discerned, the experimenter searches for procedural or measurement errors.

A recurring theme stressed by writers on this subject is that variability is more significant in the biological sciences than is currently assumed (Gedde, 1970; Harris, 1968; Motulsky, 1960; Williams, 1956). Unique mental and physical attributes are accepted and are as recognizable as individual physiognomy. Although there is no readily identified way to determine inherited constitutions or to measure the genetic differences that determine what has come to be called "biochemical individuality," these genetic differences can be indirectly assessed. From the inherited genetic background flows a wide variety of biological variables.

B. STATISTICAL APPROACHES TO BIOLOGICAL VARIABILITY

The subject of human variation has been reviewed in detail in a New York Academy of Sciences Symposium (Weyev *et al.*, 1966). The techniques of single and multivariate analysis, nonlinear factor analysis, and computer assisted analysis have been utilized in genetic and behavioral studies to evaluate the use of these statistical "tools" in studies on biological variations (Vandenberg, 1966). The main thrust of these investigations has been to understand and control variation in biological studies rather than to

search for the causes of biological variability. Statistical methods establish the probability of the mean value and not the cause or the validity of the genesis of the data. Vandenberg (1966) suggested an organized effort should be mounted to store archival data of biological facts. Longitudinal studies demand this reference base but unfortunately most publications exclude the raw data because editorial policy normally precludes their inclusion.

While the emphasis has been on inter-individual evaluations the issue of intra-individual variability remains obscure (McGammon, 1966). Both aspects of biological individuality are significant in military situations and should be considered in future research plans. In addition, the pressure of environmental factors will reflect on the inherent capacity of a man to respond to the demands of an assigned task. The genetic constitution and early environmental influences are but two aspects that have been investigated (Dubas, 1969; McKusick, 1964). Even in the most carefully controlled studies environmental variables induce fluctuations both among individuals and within individuals over time.

C. GENETIC ASPECTS OF BIOLOGICAL VARIABILITY

The characteristics of an organism are fundamentally the expression of hereditary capability as modified by environmental influences. Without belaboring the importance of the genetic mechanism, it is logical to make the basic assumption that what is inherited by an organism is a sufficient amount of genetic information which provides the capacity to respond to a range of internal or environmental stimuli.

In cases such as inborn errors of metabolism, the genetic basis of variation is alteration of a single gene, by mutation loss, or allelic substitution. These discontinuous changes are generally identifiable because of the abrupt nature of the morphologic or physiologic differences.

For example, the precise nature of and amount of cholinesterase in a man will control the degree of response to the muscle relaxant drug succinylcholine, intoxication by the organophosphorus insecticide parathion, or even the chemical warfare agents that are cholinesterase inhibitors. This single example of one enzyme system clearly points the direction for subsequent work with innumerable other enzymes.

However, subtle continuous changes in a multiplicity of enzyme systems, physiological capabilities, or behavioral responses are typical polygenic effects. Biological individuality of man is most likely an expression and repression of many genetic factors.

The enzymes of the body are proteins reflecting genetic constitution of the individual. Enzymologists have discovered an increasing number of genetic differences expressed as enzyme or protein polymorphisms. For example Harris (1968) refers to polymorphism as a variety of chemical and enzymic variants in human populations that have remarkable significance in biological functions such as reactions to different environments, diets or types of stress. More difficult to recognize as genetically controlled variants are the less dramatic but readily determined high or low levels of a specific chemical substance in blood, urine, digestive juices, or tissues of "normal" persons. These are cited as the extremes of "normal ranges" in the biochemical literature.

The most attractive element in these discoveries of enzyme polymorphism is the corresponding recognition that microsomal enzymes can be increased in activity and amount - they can be "induced" (Conney, 1967). Thus exposures to many chemicals, herbicides, food additives, environmental carcinogens, and drugs will stimulate not only their own metabolism but also the metabolism of other compounds. The toxicologic implications are obvious. Techniques have been developed for these measurements and many investigators are actively working in these fields.

Extremely sensitive and specific radioimmune assay techniques are now available to study the metabolism of drugs and substances such as nicotine in man. As expected, these studies have illustrated marked kinetic differences between individuals in the absorption, distribution and fate of these compounds. For example, large variations in nicotine metabolism among habituated and naive smokers have been noted (Haines *et al.*, 1974). However, a major factor influencing differences from person to person proved to be the increased pulmonary absorption of nicotine experienced by those individuals who smoked habitually. This variability was unexpected but illustrates how complex and interrelated human behavior and biological individuality are.

III. BIOLOGICAL FACTORS CONCERNED WITH INDIVIDUAL PERFORMANCE

For many years numerous investigators and laboratories have assessed human sensory, perceptual, and cognitive abilities as these relate to individual performance in a military environment and human engineering criteria and human factors can serve as guides to equipment design (Department of Defense, 1973; Fleishman, 1967; Joy, 1971). The psychological features of a man's performance have been evaluated and considerable success has been achieved in identifying qualities of leadership, mechanical aptitude, and similar personality variables (Kaplan, 1973). Tests have been devised to measure changes induced in performance capability by noise, drugs, vibration, and similar untoward influences. Measures include batteries of psychomotor tests such as coordination, rotary pursuit testing, manual dexterity, and response time to visual cues (Fleishman, 1960). Numerous refinements of these tests methods have been designed to evaluate specific facets of a man's performance ability. In general, the "norms" or standards are established for tasks but poor and superior performers are also identified.

The psychological makeup of the individual and the environmental components will modify the outcome of these tests. Such factors as personality, intelligence, attitude, mood, and expectations constitute what is commonly called the "set." Environmental "setting," e.g. group interaction versus solitary contemplation, or a mentally demanding milieu versus a relaxed situation, play important roles in determining the quality of a man's performance.

Some investigators have collaborated to explore the possible correlations between or among the psychological variables and the physiological and biochemical responses. However, historically the literature on behavioral performance criteria and physiology and biochemistry have been mutually foreign to scientists working in these respective fields.

The advent of psychopharmacology enhanced and encouraged the co-mingling of the several disciplines (Russell, 1960). Today the unifying effects of pharmacotherapy of mental illness have produced an extensive literature, and studies seeking biochemical correlates of human behavior are numerous involving the full range of animal studies to man by many disciplines including psychologists, neurochemists, pharmacologists, psychiatrists, and biochemists.

An important aspect of individual intellectual and physical performance related to military manpower is the phenomenon of aging. Optional or mandatory retirement does not recognize the necessary conservation of highly trained and experienced men at all levels of military operations. Essentially no research has been conducted to correlate biological individuality as a function of performance ability or decrements related to aging. The opportunities for future research in this area germane to military interests should be explored beyond the usual physical fitness examinations.

The next section of this report outlines three topics as examples of research areas where individual differences have been correlated with some biological factors that impinge on human performance. These are presented as examples for future research that could lead to an understanding of individual performance capability as reflected in a quantifiable biological measure. They are not cited in order of priority.

A. DARK ADAPTATION AND NIGHT VISION ABILITY

Night vision ability varies among individuals; however, few comprehensive studies of individual variation as it relates to night vision and dark adaptation have been made. Such factors as age, physiological state, blood sugar level and nutritional status of the individual have been identified as significant. Studies on oxygen deprivation and carbon monoxide poisoning in World War II pilots served to highlight the problem of individual variability (Berry, 1949). In these investigations, differences in visual capability and dark-adaptive capacity were observed among the normal control subjects. In addition, individual metabolic differences, genetic background, and even anatomic differences are known to be important factors controlling the individual's night vision capability (Fisher and Carr, 1970).

The adaptation rate to changing light intensity is significant in most human nocturnal activities. Fundamental differences exist between experimental laboratory studies that measure light threshold of the fully dark-adapted eye under controlled conditions and life situations that require efficient vision in an environment with changing levels of illumination. Normally the eye must continually accommodate to the visual demands of changing environmental luminance levels (McFarland and Domey, 1958; Sweeney *et al.*, 1960). For these reasons, an important distinction can be made between the night vision efficiency, as measured in test situations, and the rate of adaptation under the uncontrolled but more realistic demands of fluctuating light intensities (mesopic vision) of real life situations.

An unusual but recognizable factor that is significant in some individuals is the yellowing of the lens produced by exposure to strong sunlight. It has been suggested that the differences may be related to the metabolism

of some amino acids such as tyrosine. Another individual difference may be the disproportion of rods and blue-sensitive cones in the parafoveal areas of some eyes. Both these factors may reduce sensitivity to light in the short wave half of the spectrum to which rods (scotopic) and blue cones (photopic) are most sensitive.

Individual depth perception ability is an important factor in night vision that has been studied adequately under controlled conditions. The glare phenomenon or a sudden bright illumination followed by a decreased illumination is difficult to standardize in dark-adaptation tests. This effect may be similar to the effects of light "shock" on night vision. It is extremely difficult to study the effects of rapid changes in illumination under controlled conditions. In the "photostress test" or "macular dazzle test" (Severin *et al.*, 1963) noxious agents and drugs were shown to increase the time required for recovery of visual acuity of the subject after exposure to a standardized light flash.

One of the better understood aspects of dark adaptation and night vision is the effect of aging (Burg, 1967). Average dark-adaptation proficiency declines with increasing age. This decrease becomes significant in most persons over 55-60 years of age (Percival and Meanock, 1968). These changes in visual acuity and dark-adaptive capability are believed to be related to progressive aging of the lens, retina, optic tract, and higher central nervous system. McFarland *et al.* (1960) concluded that age is highly correlated with dark-adaptation thresholds. The assessment of age-related deviations from the norm that occur without compromising performance effectiveness is a continuing concern of both military and civilian organizations. In some instances the progressive rise in dark-adaptive thresholds may be more closely related to senescence of the lens and formation of cataracts. Identification of these individuals by proper testing would be a contribution to effective performance, especially for command responsibilities of older men.

Individuals with congenital complete color blindness and partial bilateral macular degeneration are known; presumably, cone function is completely lost but normal rod function is retained. This dysfunction of the visual process may occur to some degree in a relatively large but unknown number of individuals.

Metabolic differences may be reflected in changes in the visual process of dark-adaptation thresholds. Wilson (1965) reported that thiocyanate present in body fluids may originate from the diet or from the detoxification of cyanide. The plasma concentration and urinary excretion of thiocyanate in smokers, as compared with nonsmokers, could be interpreted as related to cyanide exposure from tobacco smoke. If a patient had an inborn error of cyanide metabolism and was unable to detoxify cyanide to thiocyanate,

such a metabolic abnormality might exhibit itself as a neurological syndrome consistent with symptoms commonly associated with chronic cyanide exposure. This type of metabolic abnormality is illustrative of individual physiological or genetic variations that may influence such an exquisitely sensitive process as vision.

1. Suggestions for Future Research

It is clear that there is a need to determine the night vision and dark adaptation capability of the individual. Differences among men may be substantial enough to influence the quality of their performance in military operations under low or fluctuating levels of ambient luminance. Analysis of the limited data suggests that within all age groups normal variations among individuals are great enough to adversely affect the execution of some military tasks carried out in partial darkness. These facts suggest that individual nocturnal tactical capabilities employing night vision devices alone or in combination with native visual capabilities in ambient light, should be evaluated by appropriate research studies.

Differences in the scotopic visual ability among men are now recognized; however, variations within the individual, over relatively short time spans, have not been adequately studied but are suspected as significant. Diurnal, seasonal, and other rhythmic fluctuations in the various biochemical, physiological, and behavioral parameters of night vision have not been explored. Studies should be supported to establish the significance of individual variability in these periodic fluctuations of vision and those rhythmic somatic responses that depend on light reception by the eyes, such as temperature and metabolic rate changes and the sleep-wake cycle. Sensitivity to light shock or dazzle can be studied by controlled techniques in human subjects. In addition to the value of predetermining the rapidity of recovery of visual acuity in the individual such studies may suggest improved methods for nuclear flash protection.

The routine determination of the night vision capability of individuals should assist in assignment to particular tasks. This could serve as a logical basis for the selection of key individuals for specific tasks.

Finally, there is a critical need to establish the range of scotopic effects of various hypoxic conditions in the military environment to prevent the individual decrements in performance that result from these adverse visual changes.

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B. REACTIONS TO MOTION

Control of motion is vital to survival. This has been true throughout the natural development of man, and it is no less true in the unnatural force and torque fields generated by modern military vehicles including new hydrodynamic ships, high performance and VTOL aircraft, and space ships. Unnatural motions induce a number of effects including direct sensory-motor reactions which influence visual information retrieval, motor coordination, and seemingly less direct effects characterized by autonomic reactions, drowsiness, headache, fear, displeasure, nausea, and vomiting. In many motion environments, most men can perform reasonably complex tasks with accuracy and reliability following a period of adjustment. However, as the performance capability of various military vehicles increases (and the tasks of individuals become more demanding), the capacities to sustain a high level of human performance may be exceeded in increasing numbers of individuals. The problems encountered over the years with motion sickness in ships, aircraft, space craft and simulators, the fact that some individuals maintain good visual acuity during motion whereas others do not, and the fact that some individuals are adaptable to motion and highly resistant to motion sickness whereas others are not, illustrate areas of individual differences which are of considerable practical significance. The fundamental basis of these individual differences is not understood. It is likely that both genetic and environmental factors are involved. Reason (1969) suggested that individual differences in susceptibility reflect characteristic differences in the transduction of sensory intensity by the central nervous system. While recognizing that reactions to motion are built in and subject to genetic influence, Guedry (1972) has adduced evidence supporting the idea that some individual differences are related to conditioning mechanisms during growth, which are related in turn to individual variations in motion reactivity, personality, and cognitive function during maturation.

The term "motion sickness" includes the symptoms of vague malaise, pallor, cold sweating, nausea, and vomiting. Its impact on efficient human performance in military situations is obvious and has been the subject of much research (Fisher and Carr, 1973).

Individual variations in symptom and sign expression to motion are both quantitative and qualitative. The effects of motion on a person probably form a continuum of different responses that include a wide range of variables. A number of investigators have studied individual susceptibility to motion sickness, and classified the patterns of response as resistant or susceptible. Results of investigations, theoretical aspects, and usefulness of current selection procedures were topics discussed at a recent AGARD symposium on predictability of motion sickness in selection (1972). These aspects of susceptibility prediction may provide clues to the fundamental basis of individual variation.

Techniques to identify individuals who can be classified as resistant or susceptible to various causes of motion sickness have been developed for preselection, experimental study of response patterns and adaptation to motion. Few studies have utilized combinations of these methodologies to investigate individual differences *per se*. The existence of intra-and inter-individual differences in resistance or susceptibility to motion sickness should be exploited in future research studies.

The neurohumoral transmitter substances involved in these neural pathways concerned with motion can be estimated by biochemical analyses. It may prove useful to include these parameters in studies designed to assess the susceptibility of individuals to motion sickness.

Individual differences in motion disturbance susceptibility are related to labyrinthine function and persons lacking a labyrinth mechanism are immune to motion sickness. Additional studies should be made on individual differences in vestibular information as a predictor of motion disturbance susceptibility according to the approach developed by Moore and Guedry (1974).

1. Suggestions for Future Research

Only a few of the many variables suspected to be related to individual differences in reaction to motion and susceptibility to motion sickness have been studied. Early influences of environmental stimuli related to various types of body motion, quantifiable responses to controlled vestibular, visual and other proprioceptive stimuli during childhood and adolescence, neurochemical and neurophysiological differences in susceptible and resistant individuals, and refined techniques for the early identification of the susceptible or resistant person should be investigated. It is possible to discover from such studies the basic features of biological individuality that lead to "adaptivity" or "resistivity" in men to motion stress. The recurrent theme of preselection of those individuals for specific tasks would be emphasized in these studies.

The study of the performance abilities of men who do not adapt readily to motion may yield useful information on their reliability in executing certain critical military tasks. In addition, it may be possible to identify individuals who can continue to perform effectively while suffering from some degree of motion sickness.

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C. SENSITIVITY TO NOISE EXPOSURE

Audiologists, otologists, and others trained in clinical evaluation of hearing recognize wide variability in the human auditory system. This biologic variation is reflected in the range of normal hearing ability, the sensitivity of hearing, and the response to potentially hazardous noise fields (Burns, 1968; Stewart and Burgi, 1964). In addition to neurophysiological variability which is essentially an unknown, individual anatomical, psychological, and sociological factors affect each person's response to noise. Thus attempts to quantify noise effects within a population over a

prolonged period of time usually exhibit variability among and within individuals over time. The adverse biomedical effects of sound in the military environment have been reviewed by Carr and Fisher (1971).

Ward (1965) suggested that individual physiological differences might be associated with the static or the dynamic characteristics of the middle ear, or attributable to features of the inner ear. Static characteristics of the middle ear might reflect differences in sound pressure levels in or the size and shape of the external auditory canal and consequently differences in hydrodynamic pressures in the cochlea and the tympanic membrane or oval window. There has been little research on these aspects of hearing differences. In addition, individual differences in the strength and reaction of the middle ear muscles may be a possible dynamic basis for differences in threshold shifts. Ward (1965) noted that differences in the strength of contraction and the rate of adaptation could alter the effect of the aural reflex on threshold shift.

Threshold testing and hearing loss evaluation involving subjective responses superimpose the psychological variables upon the physiological factors. Although the physiological responses are poorly understood the psychological factors are most frequently and readily measured (Taylor *et al.*, 1965). The normal variation of temporary threshold shifts among individuals is evident in large-scale tests, although repeated testing often discloses less individual variation in successive tests than that observed in single tests of different individuals (Hirsh and Ward, 1952).

Hearing loss surveys frequently uncover differences between males and females (Corson, 1963; Gallo and Glorig, 1964; Ward, 1966; Ward *et al.*, 1959). Most investigators have concluded that these sex differences can be attributed to greater noise exposures sustained by males in military service, occupations, and recreational activities. Thus differential exposure rather than differential susceptibility to noise is the assumed and generally accepted explanation. However, Ward (1966) observed less temporary threshold shifts in females than in males exposed to noise in the 1400 to 2800 Hz part of the spectrum and attributed this difference to more efficient middle ear muscle function.

The readily measurable intra- and intersubject variability in auditory threshold, temporary threshold shifts and hearing loss has fostered a concept of "susceptibility" to noise-induced hearing loss. This concept holds that certain individuals are more susceptible and others are more resistant to both the temporary and permanent deleterious effects of noise because of anatomical, physiological, and psychological differences. The bases of these differences in susceptibility are not known with certainty. If individuals extremely susceptible to temporary threshold shifts could be identified audiometrically, and if this susceptibility to temporary

threshold shifts reflected an auditory system more sensitive to permanent threshold shifts, then individuals likely to be permanently affected by noise could be identified and protected against excessive exposures.

As a corollary, some individuals may be markedly resistant to temporary threshold shifts and perhaps permanent threshold shifts. Thus, identification of such persons could be useful in selecting individuals who would tolerate excessive noise exposures with reduced risk of permanent hearing loss. Men with superior ability to discriminate speech and other meaningful auditory information in situations with a low signal to noise ratio might be detected by similar studies.

1. Suggestions for Future Research

It is not possible at the present time to identify individuals who will have an increased susceptibility to noise. However, individual sensitivity to high noise intensity can be recognized and many of the physiological and anatomical effects of noise exposure leading to hearing deficits are known. It is suggested that the readily measured intra- and intersubject variability in auditory threshold is a means of identifying those individuals unduly susceptible to temporary or permanent noise-induced hearing loss. The characteristics of the noise, as well as the anatomical, physiological, and psychological differences have been studied but more research should be conducted on this subject to insure the preselection of men and women with the ability to achieve the military requirements of their duties without undue noise effects. Audiometric monitoring and hearing conservation programs will prevent significant noise-induced hearing loss as a result of working and living in a high intensity sound environment; however, individual preselection based on the proper criteria would enhance many facets of military performance of men. Such techniques need to be correlated with future planning for the most efficient utilization of modern military operations exposing men to high intensity sounds.

Nonauditory, somatic responses to noise are recognized but are not fully investigated. Adaptability to noise in terms of the disappearance or reduction of somatic responses such as changes in blood pressure, vasomotor tone, respiratory rate, gastrointestinal motility, and galvanic skin response is poorly understood (Kryter, 1970). Studies of somatic responses to noise in terms of individual differences may determine the significance of somatic reactions in performance of military personnel and would develop information for selection and training.

The variability of the characteristics of the inner ear has not been studied in great detail. These include: geometry and composition of the cochlear partition, density and spacing of epithelial hair cells, size and shape of the tectorial and basilar membranes, biochemical composition

of the endolymph, variations of the cochlear blood supply, rates of oxygen utilization and carbon dioxide removal within cochlear cells, and density of afferent and efferent innervation. Fundamental knowledge of this character may explain many individual differences in sensitivity to noise exposure.

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